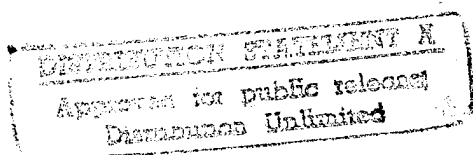


FIREBALL CALCULATIONS
SHOT WRANGELL
OPERATION HARDTACK, PHASE II
PROJECT 15.1



Report No. B-2064
4 March 1960

19960702 074

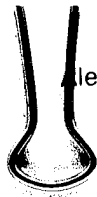
Prepared by

J. E. Campbell
J. E. Campbell

Approved by

D. F. Seacord, Jr.
D. F. Seacord, Jr.

EDGERTON, GERMESHAUSEN & GRIER, INC.
Boston, Mass. Santa Barbara, Calif. Las Vegas, Nev.



Defense Nuclear Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398



ISST

29 May 1996

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OCD/MR. BILL BUSH

SUBJECT: Documents for DTIC System

There is no record of your office receiving the following reports:

EGG-B-2064 (4 March 1960)
Fireball Calculations Shot
Wrangell Operation Hardtack
Phase II, Project 15.1

EGG-B-2063 (4 March 1960)
Fireball Calculations Shot Humboldt
Operation Hardtack Phase II
Project 15.1

Both documents are now approved for public release.

Therefore, we are transmitting copies for inclusion into the DTIC system, if not found there.

Enclosure:
A/S

Arldith Jarrett
ARDITH JARRETT
Chief, Technical Support

DTIC QUALITY INSPECTED 4

FIREBALL CALCULATIONS - SHOT WRANGELL

1.0 INTRODUCTION

Shot Wrangell was a 1500-foot balloon shot sponsored by LRL and detonated on 22 October 1958 in Area B-Fa of the Nevada Test Site at 0850 PST.

The fireball yield was $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

2.0 CAMERA INSTRUMENTATION AND OPERATION

Photographic coverage of fireball growth was provided by four high-speed Eastman cameras, two each at Station F-362 (6 x 6 No. 2) and Station F-369 (6 x 6 No. 3). In addition, two Rapatronic cameras were located at each of these stations to record early fireball growth.

Three Eastman cameras and three Rapatronics provided good records. The remaining Eastman and Rapatronic, because of malfunctions, did not provide records suitable for analysis.

The station locations, together with the burst location, are shown in Figure 1. Figure 2 contains the Survey Data.

3.0 RESULTS

Application of phi-comparison (EG&G Report No. B-1869) for Shot Wrangell indicates a yield of $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

An air density of 1.057 grams per liter was used in the yield calculations, based on a pressure of 863 millibars, a temperature of 11.1°C , and a relative humidity of 13 percent at the height of the device at shot time.

The following table shows the Wrangell yield as obtained by a phi-comparison to various other low-yield devices:

Comparison Shot	Wrangell Yield Tons
<u>Air Drop</u>	
Wasp	66.74
Buster Baker	62.41
Wasp'	66.38
Ranger E	63.56
Ranger A	66.73
Osage	71.64
<u>Tower</u>	
Hornet	64.97
Chaves	72.97
Rio Arriba	73.19
Quay	64.44
Humboldt	64.58
<u>Balloon</u>	
Hidalgo	66.46
Lea	71.03
$\bar{W} = 67.3 \text{ tons}$	

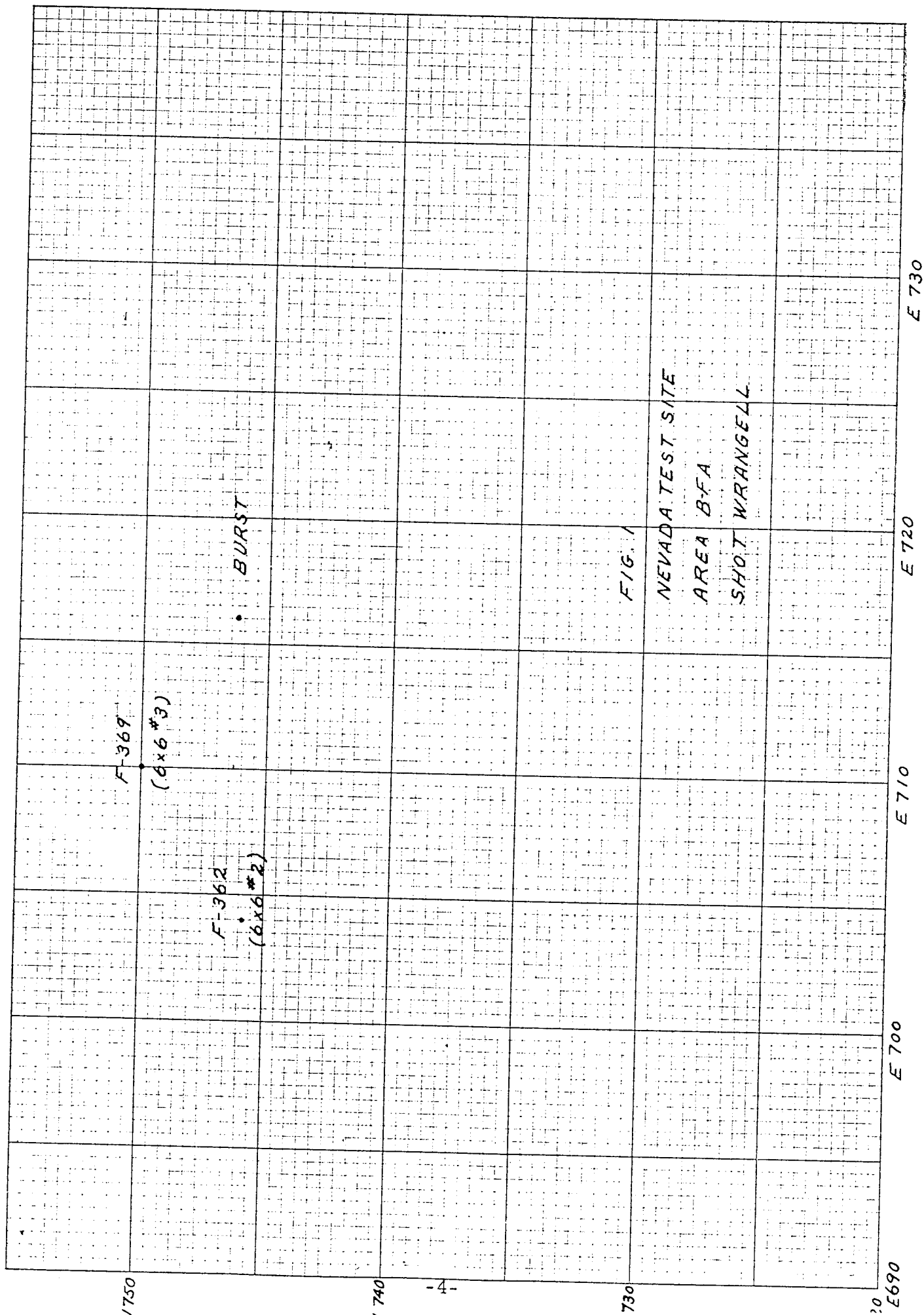
Diameter-time and phi-time plots are shown in Figures 3 and 4.

The following data sheets are included for each film:

- (a) Photo Plan and Photo Loading Chart
- (b) Camera Data and Calculation Sheet
- (c) Diameter Measurement Sheet
- (d) E-102 Print-Out Sheet of D , t , and \emptyset

Appendix A contains photographic examples of early fireball growth.

The zero-frame times of the Eastman records were determined by comparison with the Rapatronic diameter-time data.



DATE 10/22/58

SURVEY DATA

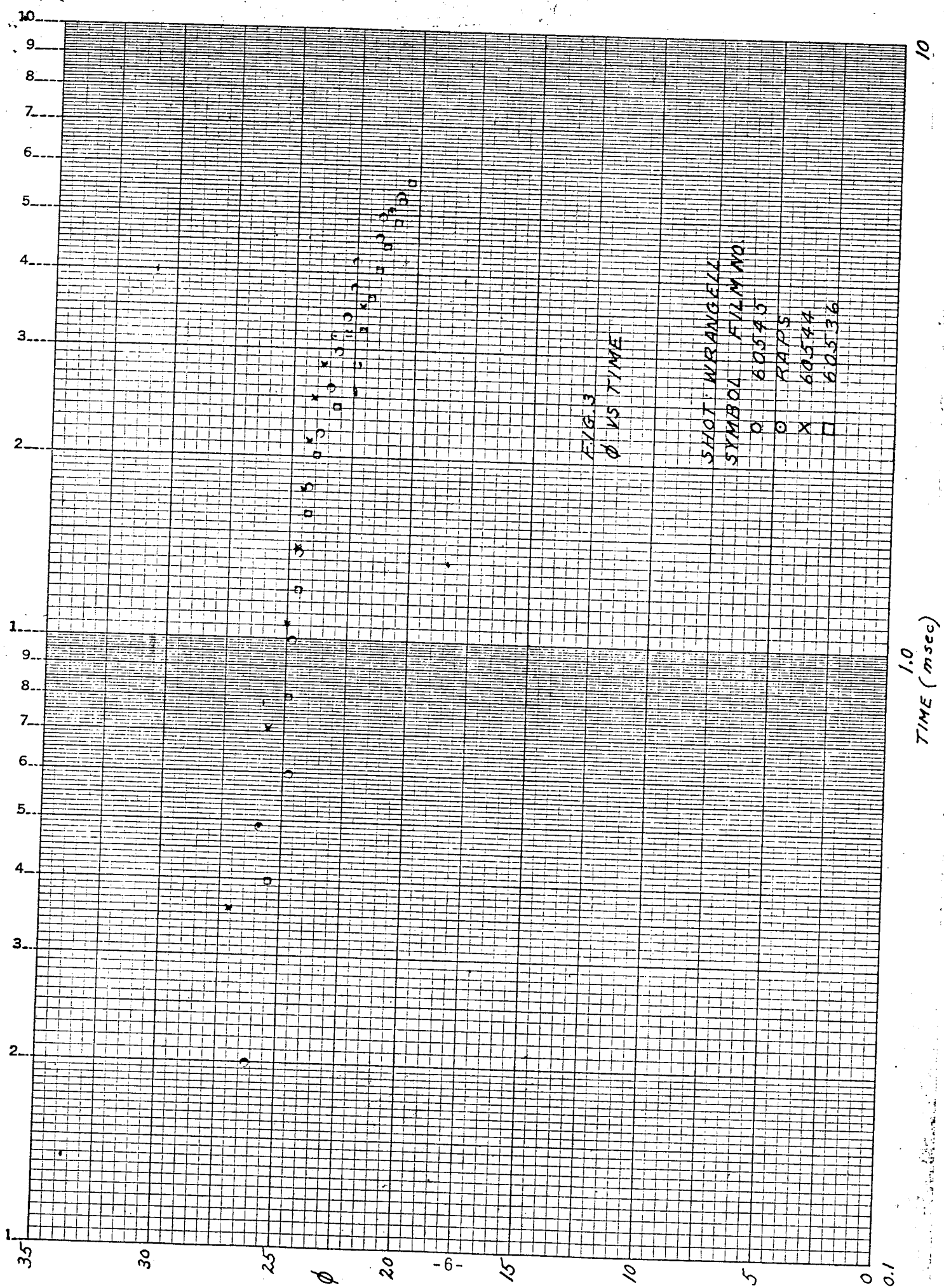
BFA
GZ STA.

[illegible]

FORM E17(1-55 500)

NAME ANALYSIS

EDGERTON, GERMESHAUSEN & GRIER INC.



TIME (msec)

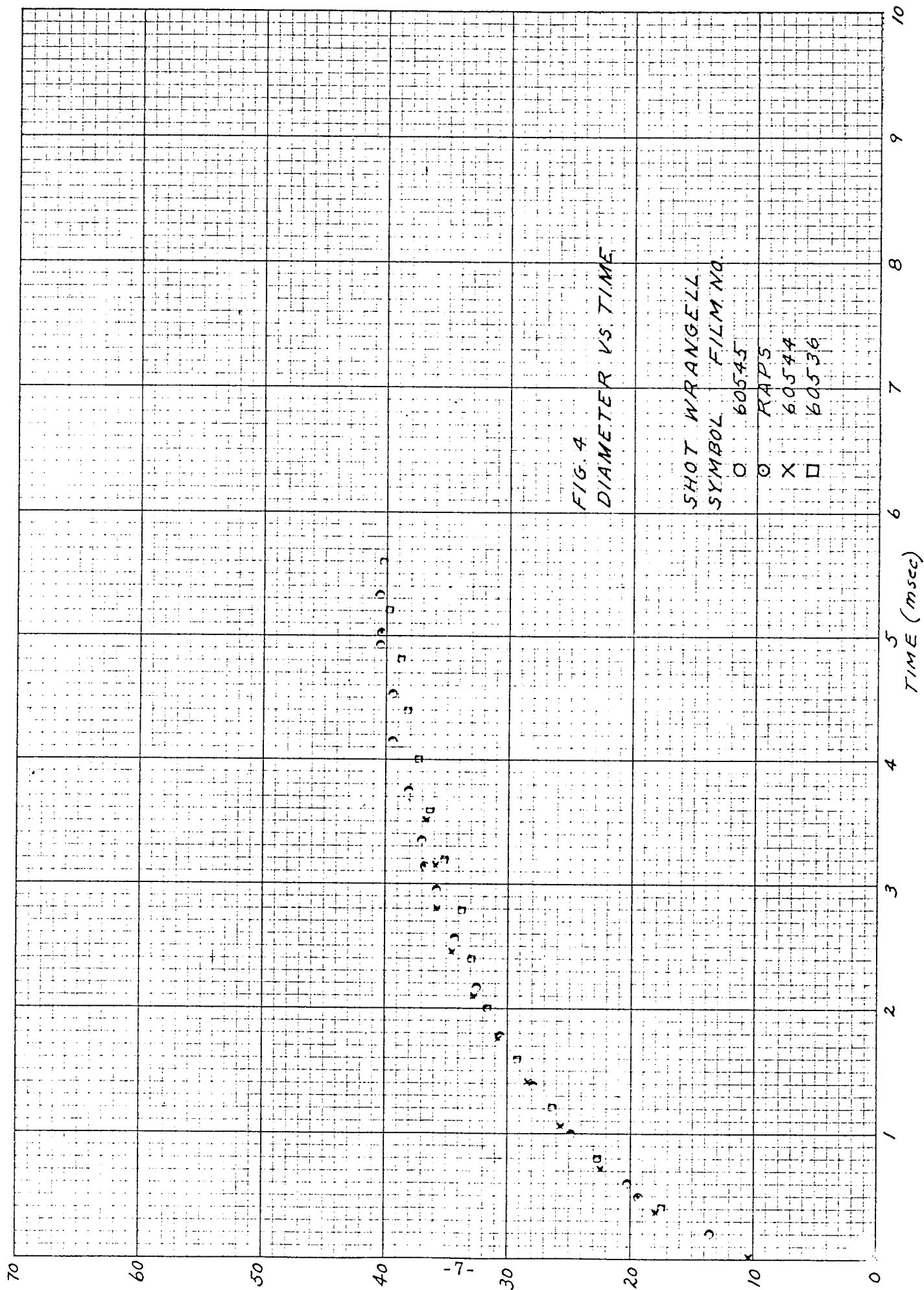


Table I
 Hardtack Phase II, Wrangell.
 Average Diameter vs. Time

Time (msec)	Diameter (Meters)
0.5	19.5
1.0	25.0
1.5	29.0
2.0	32.0
2.5	34.0
3.0	36.0
3.5	37.5
4.0	38.5
4.5	39.0
5.0	40.0
5.5	40.5

Table II

Hardtack Phase II - Wrangell

Rapatronic Summary

Station	Film No.	Camera No.	Range (m)	F. L. (mm)	Diameter (m)	Time (ms)
F-362 (6 x 6 No. 2)	60540	R-34	3704.1	479.03	36.88	3.17
	60539	R-30	3704.1	479.30	19.41	0.49
F-369 (6 x 6 No. 3)	60548	R-4	2196.3	477.82	40.32	5.07
	60547	XR-7	2196.3	481.92	Malfunction	

STATION NO.	F-362
STATION TYPE	6 x 6 No. 1
DISTANCE GZ	12,058.8 ft
DISTANCE OBJECT	12,149.3 ft

PHOTO PLAN		BRG	88°04'	EVENT	WRANGELL
GZ	TILT	GZ	-0°04'	GZ STA.	BFA
746250	DIFF.			DATE	10/22/58
716000	406	OBJ	7°01'	POSTED	11/5/58
4577*	12052				
	1486				

STATION
N 745844
E 703948
Z 3091

GZ	DIFF.
<u>746250</u>	<u>406</u>
<u>716000</u>	<u>12052</u>
<u>4577*</u>	<u>1486</u>

TILT
GZ -0°04'
OBJ 7°01'

GZ STA. *BFA*
DATE *10/22/58*
POSTED *11/5/58*

[illegible]

REMARKS	* INCLUDES 1500 FEET, HEIGHT OF BALLOON
---------	---

76N13

435

EDGERTON, GERMESHAUSEN & GORE, INC.

PHOTO LOADING CHART

STATION F-362 (6x6 No. 1)

EVENT WRANGELL

DATE 10/18/58

[illegible]

FORM E-40

FINAL

EDGERTON, GERMESHAUSEN & GRIER, INC.

PHOTO PLAN

STATION TYPE 6X6 #2 STATION N 745 825 GZ 746 250 DIFF. -425 BRG 87°59' EVENT WRANBELL
 DISTANCE GZ 12 061.5 ft. DISTANCE OBJECT 12152.0 ft. Z 3 090 GZ 716 000 TILT -0° 4' GZ STA. B - FA
 DATE 10-22-58 POSTED 1487

CAMERA			LENS			FIELD TARGET		AIMING		POWER			MARKER		DELAY	FILM	PUR-POSE	REMARKS
NO.	NOM SPD.	RACK POS.	FOC. MM	S/N	FILTER	H/V		OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N			
E-34	2500	C-1	153	RC 540	ND-1	.720		F.B.	0° 00'	702	120DC	40/80	-1.5/11.5	200	12		MF	15.1
E-7	2500	C-2	102	RC 128	ND-1	1.072		F.B.	0° 00'	702	120DC	40/80	-1.5/11.5	200	4		MF	15.1
M-26	100	B-2	25	BF8787	W-12	12.013		CLOUD	0° 00'	1420	120DC	170	-5/130	200	12		TRI-X	15.1
R-30	400	A-1	480	773953	ND-1	1.267		F.B.	0° 00'	702	24DC	RULE		FM	5		RP	15.1
R-34	400	A-2	480	773948		1.267		F.B.	0° 00'	702	24DC	RULE		FM	5		RP	15.1
32						13.314			0° 00'	1515	24DC	133	-5/130					CAN #40
35P	64	B-4	95	240190		9.000		D.C.	0° 00'	1515	24DC	133	-5/130				KDC	15.1
GSP	64	B-4	95	240259		9.000		D.C.	0° 00'	1515	24DC	133	-5/130				KDC	15.1
#1						1.168		F.B.	0° 00'	702	120DC		-3/12	200	4		ECT	15.1
35EE	2000	C-3	254	808160	ND-3	.795											1229	15.1
								ACTUAL RPP DELAYS										
								R-30			482.1	45	+	2.45			half coil	delay
								R-34			3148.7	45	+	20.45			half coil	delay

REMARKS * Includes 1500 feet height of balloon

PHOTO LOADING CHART

STATION F362 6X6 2 #2 EVENT WRANGELL DATE 10-22-58

STATION F362 6X6 2 #2 EVENT WRANGELL DATE 10-22-58

[illegible]

DATE FILM LOADED	DATE CAMERA LOADED	DATE EXPOSED
10/18/58		

REMARKS

5, 20, 25

FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

PHOTO LOADING CHART

STATION F 369 - 6X6 #3 EVENT W/RANGELL DATE 10-18-58

DATE 10-18-58

[illegible]

DATE FILM LOADED 10/18/58 DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS

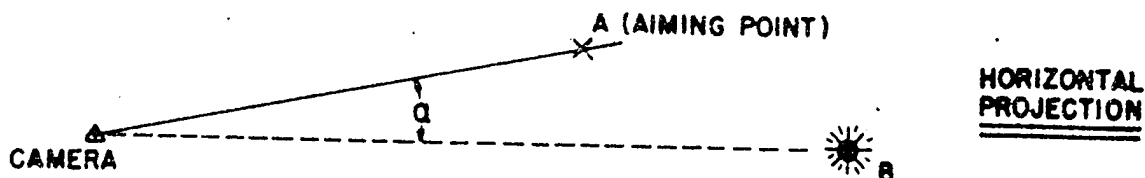
FINAL

FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

CAMERA DATA & CALCULATIONS

FILM NO. 60539	STATION NO. <i>F-362</i> <i>6x6 No. 2</i>	TEST <i>WRANGELL</i>	CALCULATED BY: <i>JEC</i>
CAMERA NO. <i>R-30</i>	EQ. AP.	DATE: <i>12/2/58</i>	



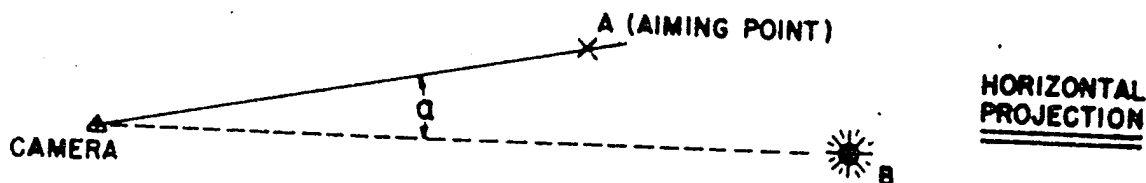
A. $R^{\circ}A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$		
$\alpha = 0^{\circ}00'$	$\beta = 7^{\circ}02'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.99248$	$H_C = 3090 \text{ ft}$
$CB_h = 3676.2 \text{ m}$	$\sin \beta = 0.12245$	$\Delta H = 1487 \text{ ft} = 453.2 \text{ m}$
$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$	$\Delta H \sin \beta = 55.5 \text{ m}$	$R^{\circ}A = \boxed{3704.1 \text{ m}}$
B. FOCAL LENGTH <i>479.30 mm</i>		

C. MAGNIFICATION FACTOR (meters/in.) <i>196.29</i>
--

D. ZERO TIME CORRECTION <i>0.49 msec delay</i>
--

CAMERA DATA & CALCULATIONS

FILM NO. 60540	STATION NO. <i>F-362</i> <i>6x6 No. 2</i>	TEST <i>WRANGELL</i>	CALCULATED BY: <i>JEC</i>
CAMERA NO. <i>R-34</i>	EQ. AP.	DATE: <i>12/2/58</i>	



A. $R^0_A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$

$\beta = 7^\circ 02'$

$\cos \alpha = 1.00000$

$\cos \beta = 0.99248$

$H_B = 4577 \text{ ft}$

$CB_h = 3676.2 \text{ m}$

$\sin \beta = 0.12245$

$H_C = 3090 \text{ ft}$

$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$

$\Delta H \sin \beta = 55.5 \text{ m}$

$\Delta H = 1487 \text{ ft} = 453.2 \text{ m}$

B. FOCAL LENGTH 479.03 mm

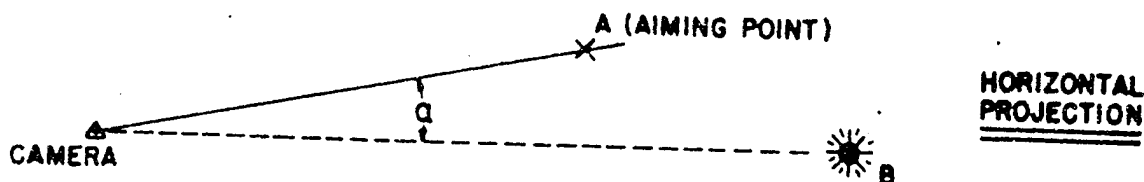
$R^0_A = \boxed{3704.1 \text{ m}}$

C. MAGNIFICATION FACTOR (meters/in.) 196.41

D. ZERO TIME CORRECTION 3.17 msec delay

CAMERA DATA & CALCULATIONS

FILM NO. 60548	STATION NO. F-369 6x6 #3	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. R-4	EQ. AP.		DATE: 12/2/58



A. $R^0/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$	$\beta = 12^\circ 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^0/A = \boxed{2196.3 \text{ m}}$

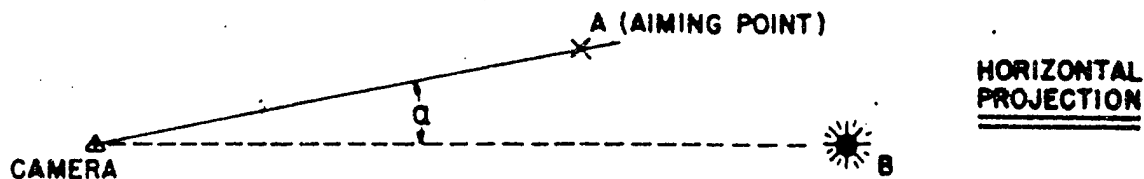
B. FOCAL LENGTH 477.82 mm

C. MAGNIFICATION FACTOR (meters/in.) 116.75

D. ZERO TIME CORRECTION 5.07 msec delay

CAMERA DATA & CALCULATIONS

FILM NO. 60545	STATION NO. ^{F-369} 6x6 No. 3	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-6	EQ. AP.		DATE: 12/2/58



A. $R^{\circ}/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^{\circ} 00'$	$\beta = 12^{\circ} 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^{\circ}/A = \boxed{2196.3 \text{ m}}$

B. FOCAL LENGTH 63.91 mm (ET1254)

C. MAGNIFICATION FACTOR (meters/in.) 872.9

D. ZERO TIME CORRECTION 0.20 msec $\frac{1}{2}$ frame

DIAMETER MEASUREMENTS

SHOT WRANGELL

FILM NO. 60545

[illegible]

READ BY JEC GGO

TYPED BY

DATE 11/4/58

DATE _____

REMARKS:

FIREBALL CALCULATIONS

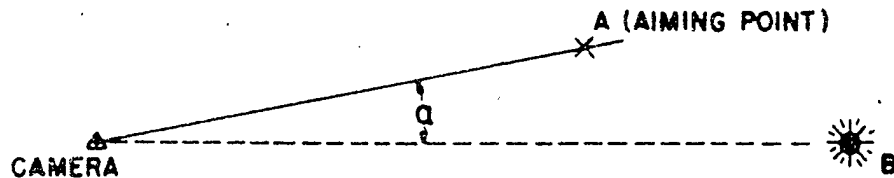
SHOT WRANGELL FILM NO. 60545

DATE _____

D	t	ln D	Int	t ^{2/5}	φ
13.70	.20	2.61742	1.60945 -	.525303	260.80
2017	.60	3.00418	510.90 -	8151.07	247.43
2468	1.00	3.20592	07	10.00031	246.79
2784	1.39	3.32642	329.33	11.40806	244.03
3040	1.79	3.41442	582.26	12.62262	240.83
3236	2.19	3.47693	783.85	13.68260	236.50
3416	2.59	3.53109	951.58	14.63210	233.45
3567	2.98	3.57436	1091.89	15.47680	230.47
3702	3.38	3.61152	1217.90	16.27692	227.43
3808	3.78	3.63976	1329.79	17.02194	223.71
3943	4.18	3.67460	1430.38	17.72080	222.50
3943	4.57	3.67460	1519.56	18.36433	214.70
4048	4.97	3.70089	1603.43	18.99084	213.15
4064	5.37	3.70483	1680.79	19.58774	207.47

CAMERA DATA & CALCULATIONS

FILM NO. 60544	STATION NO. ^{F-369} 6x6 No. 3	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-25	EQ. AP.		DATE: 12/2/58



HORIZONTAL
PROJECTION

A. $R^0_A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$	$\beta = 12^\circ 00'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.97815$	$H_C = 3078 \text{ ft}$
$CB_h = 2148.2 \text{ m}$	$\sin \beta = 0.20791$	$\Delta H = 1499 \text{ ft} = 456.9 \text{ m}$
$CB_h \cos \alpha \cos \beta = 2101.3 \text{ m}$	$\Delta H \sin \beta = 95.0 \text{ m}$	$R^0_A = \boxed{2196.3 \text{ m}}$

B. FOCAL LENGTH 101.8 mm (RA 549)

C. MAGNIFICATION FACTOR (meters/in.) 547.9

D. ZERO TIME CORRECTION 0.01 msec 0.01 frame

DIAMETER MEASUREMENTS

SHOT WRANGELL

FILM NO. 60544

[illegible]

READ BY JEC GGO

TYPED BY

DATE 11/4/58

DATE _____

REMARKS :

FIREBALL CALCULATIONS

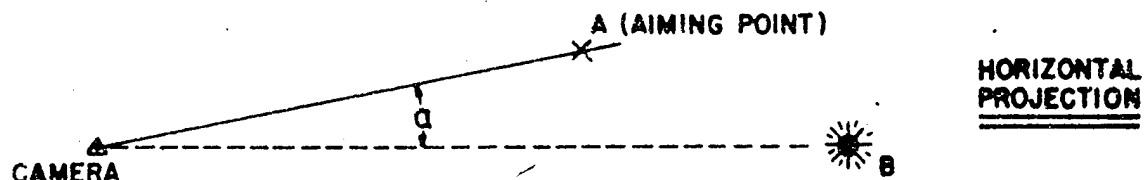
SHOT WRANGELL FILM NO. 60544

DATE _____

D	t	ln D	Int	$t^{2/5}$	ϕ
10.36	.01	2.33795	4.60509 -	.159064	651.30
17.87	.36	2.88317	1.02159 -	6.64553	268.90
22.30	.71	3.10453	3.4253 -	8.71956	255.74
25.49	1.06	3.23821	5.822	10.23565	249.03
28.17	1.42	3.33820	7.5070	11.50597	244.82
30.50	1.77	3.41771	5.7103	12.56604	242.71
32.60	2.12	3.48433	7.5137	13.50603	241.37
34.42	2.48	3.53868	9.0818	14.38027	239.35
35.73	2.83	3.57605	1.04022	15.16022	235.68
36.02	3.18	3.58413	1.15688	15.88441	226.76
36.70	3.54	3.60284	1.26417	16.58009	221.33

CAMERA DATA & CALCULATIONS

FILM NO. 60536	STATION NO. ^{F-362} _{6x6 No. 2}	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-34	EQ. AP.		DATE: 12/2/58



A. $R^0/A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

$\alpha = 0^\circ 00'$	$\beta = 7^\circ 02'$	$H_B = 4577 \text{ ft}$
$\cos \alpha = 1.00000$	$\cos \beta = 0.99248$	$H_C = 3090 \text{ ft}$
$CB_h = 3676.2 \text{ m}$	$\sin \beta = 0.12245$	$\Delta H = 1487 \text{ ft} = 453.24 \text{ m}$
$CB_h \cos \alpha \cos \beta = 3648.6 \text{ m}$	$\Delta H \sin \beta = 55.5 \text{ m}$	$R^0/A = \boxed{3704.1 \text{ m}}$

B. FOCAL LENGTH 152.8 mm (RC 540)

C. MAGNIFICATION FACTOR (meters/in.) 615.7

D. ZERO TIME CORRECTION 0.40 msec (0.99 fr)

DIAMETER MEASUREMENTS

SHOT WRANGELL

FILM NO. 60536;

[illegible]

READ BY GGO JEC TYPED BY _____

DATE 11/4/58 DATE _____

REMARKS:

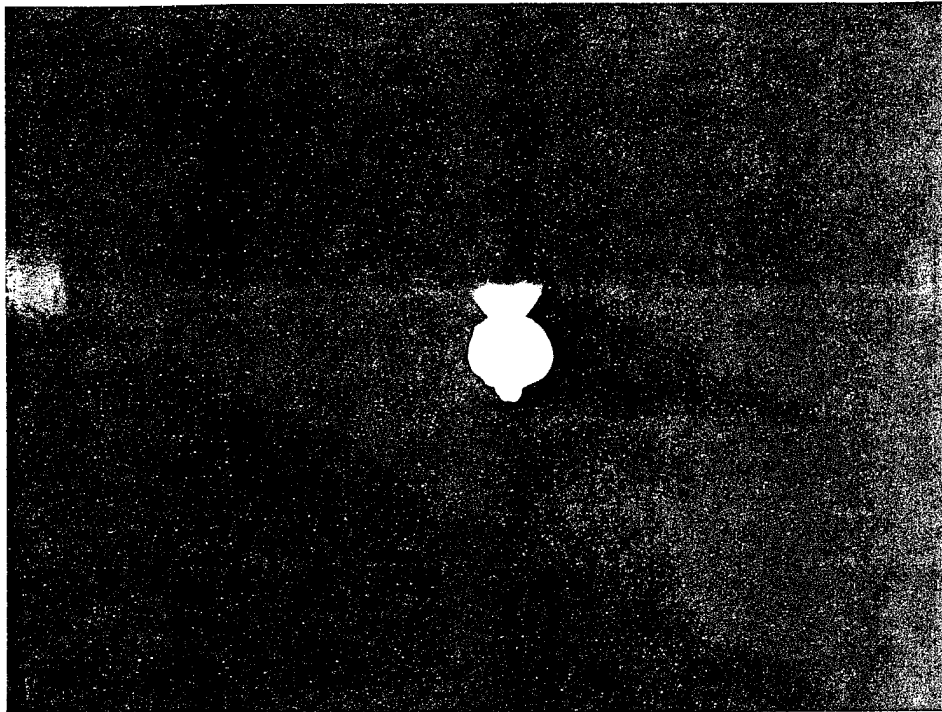
FIREBALL CALCULATIONS

SHOT WRANGELL FILM NO. 60536

DATE _____

D	t	ln D	Int	$t^{2/3}$	ϕ
17.59	.40	2.86739	.01621 -	.693164	25376
22.70	.80	3.12230	22311 -	9.14622	24818
26.28	1.21	3.26874	19056	10.79205	24351
29.10	1.61	3.37070	47631	12.09884	24051
31.53	2.02	3.45094	70308	13.24763	23800
32.87	2.42	3.49258	88369	14.24009	23082
33.77	2.82	3.51960	103668	15.13876	22306
35.11	3.23	3.55853	117249	15.98390	21965
36.39	3.63	3.59436	128929	16.74839	21727
37.41	4.04	3.62201	139632	17.48098	21400
38.31	4.44	3.64578	149071	18.15364	21103
38.88	4.85	3.66056	157900	18.80618	20674
39.78	5.25	3.68344	165820	19.41155	20492
40.35	5.65	3.69767	173160	19.98986	20185

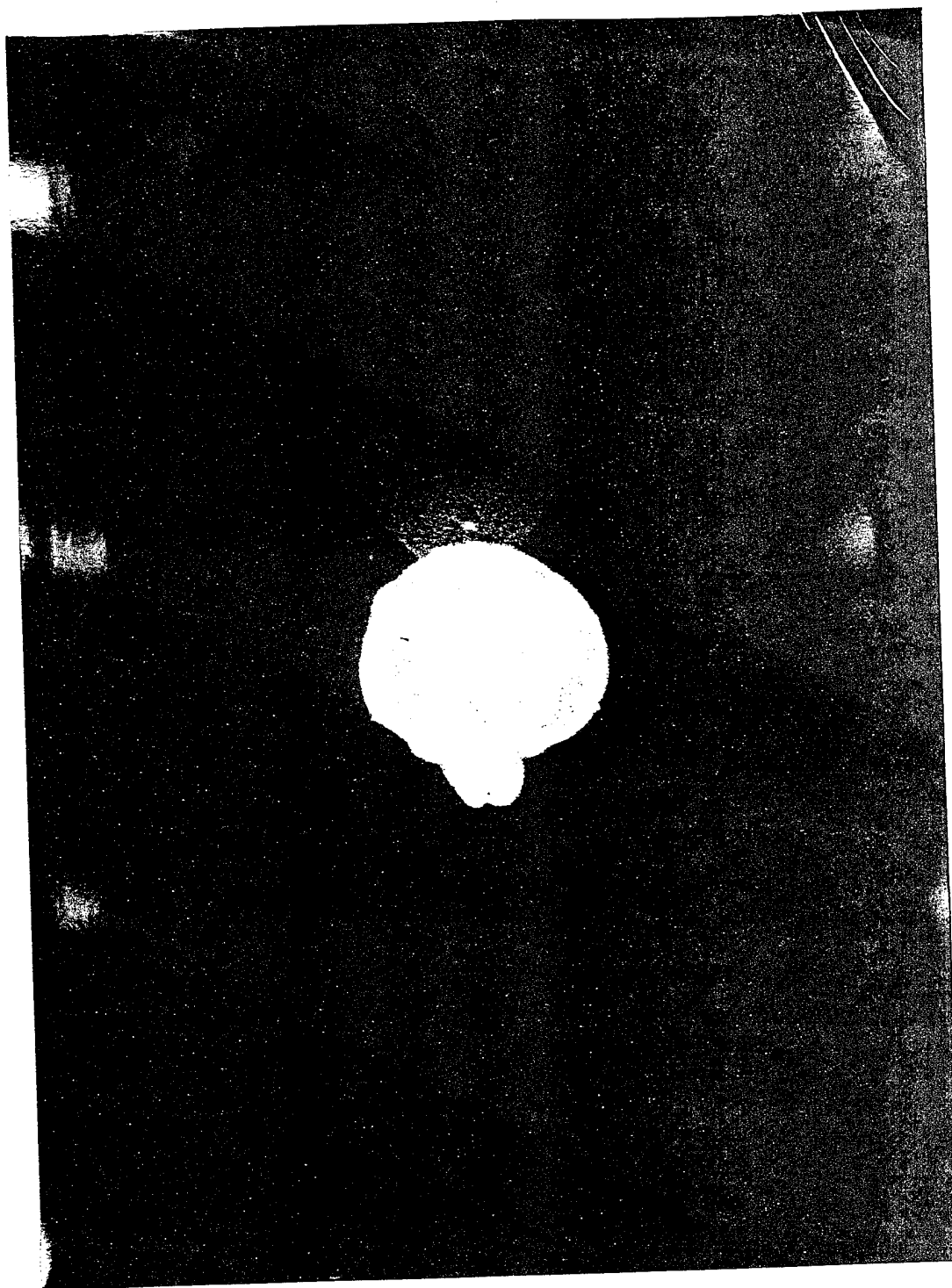
APPENDIX A
HARDTACK PHASE II, WRANGELL
PHOTOGRAPHIC EXAMPLES



Camera: E-34

Station: F-362 (6 x 6 No. 2)

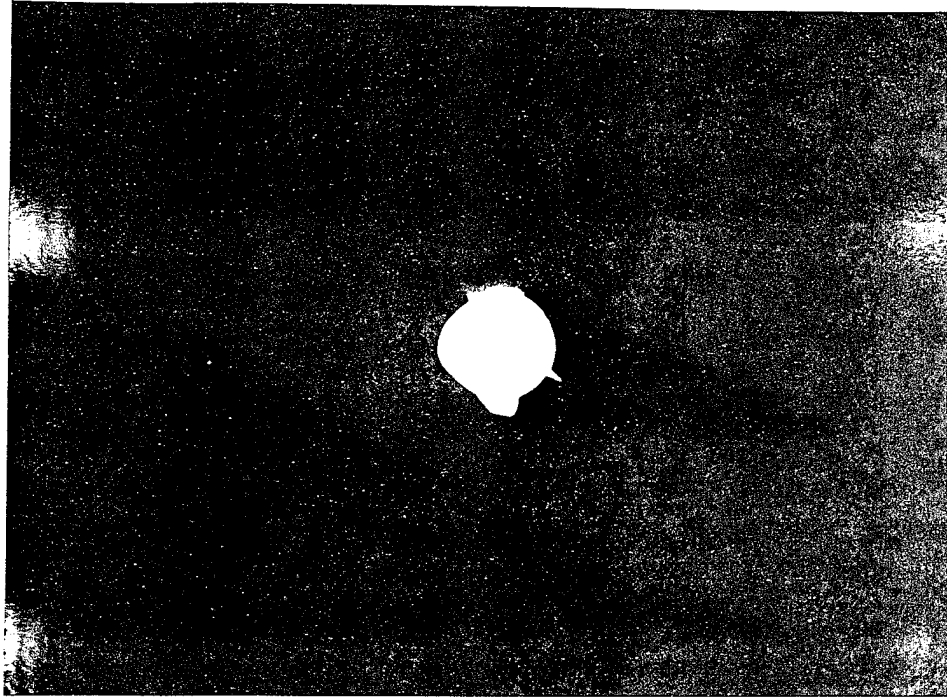
Time: 0.40 msec



Camera: R-30

Station: F-362 (6 x 6 No. 2)

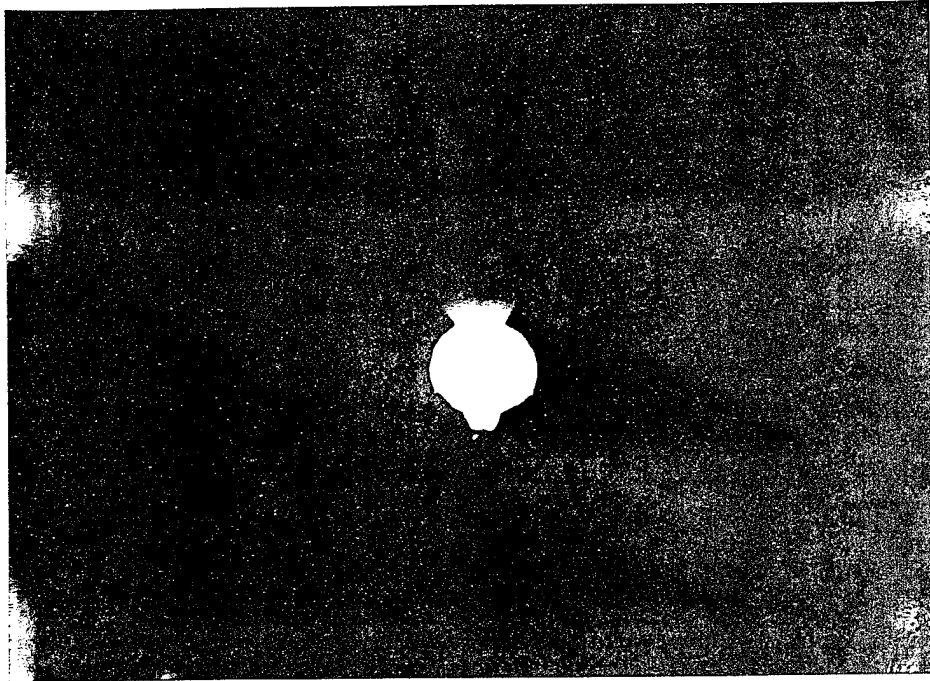
Time: 0.49 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

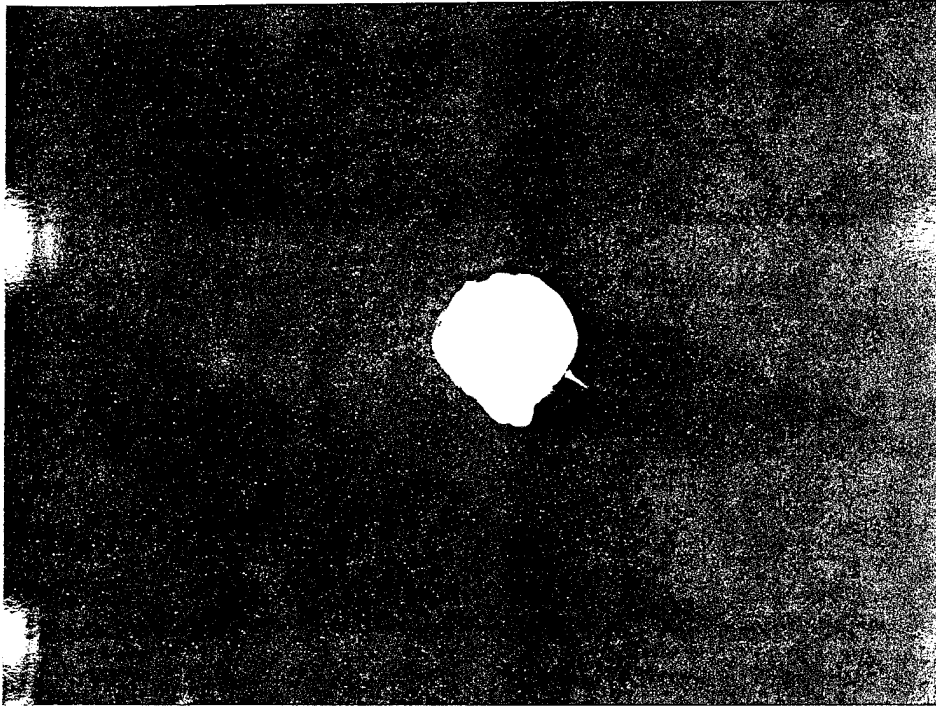
Time: 0.71 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

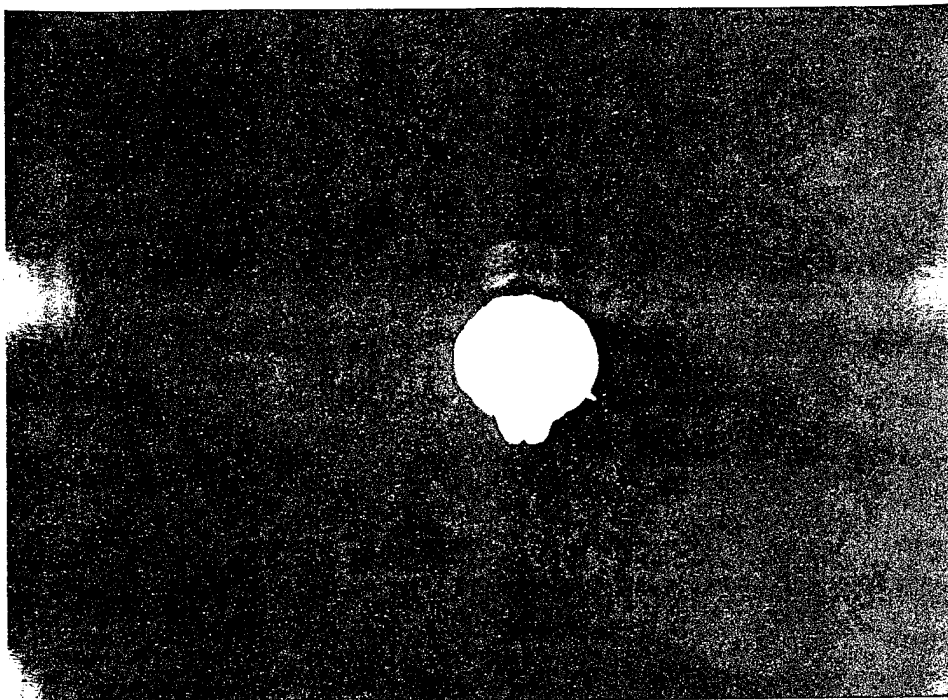
Time: 0.80 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

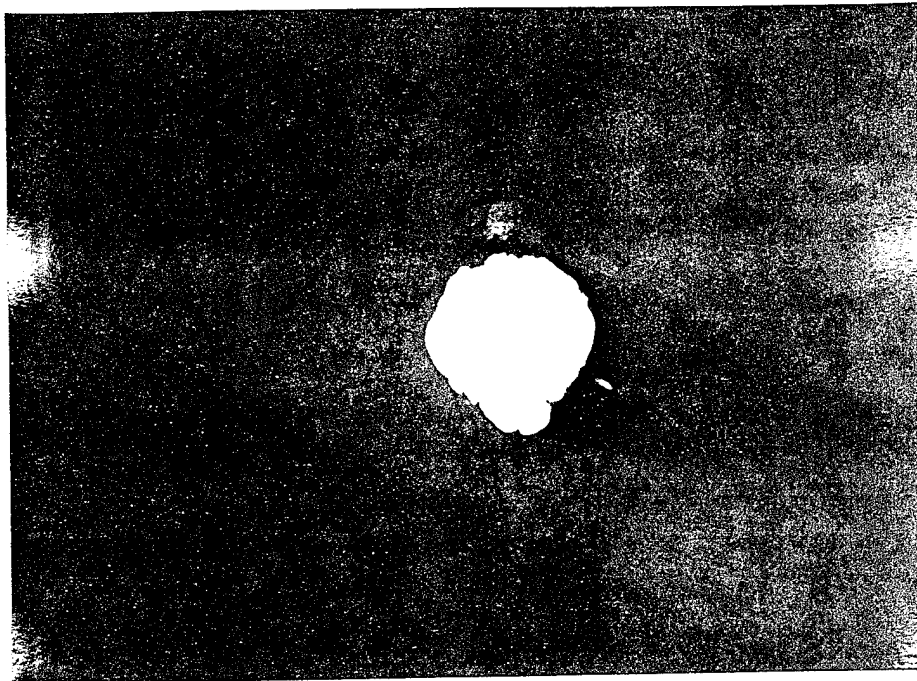
Time: 1.42 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

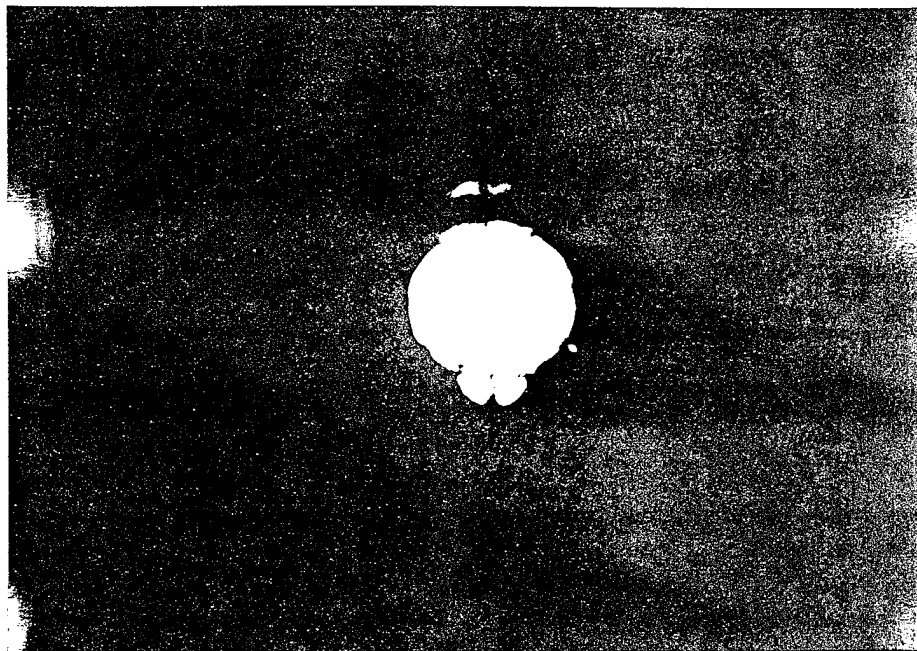
Time: 2.02 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

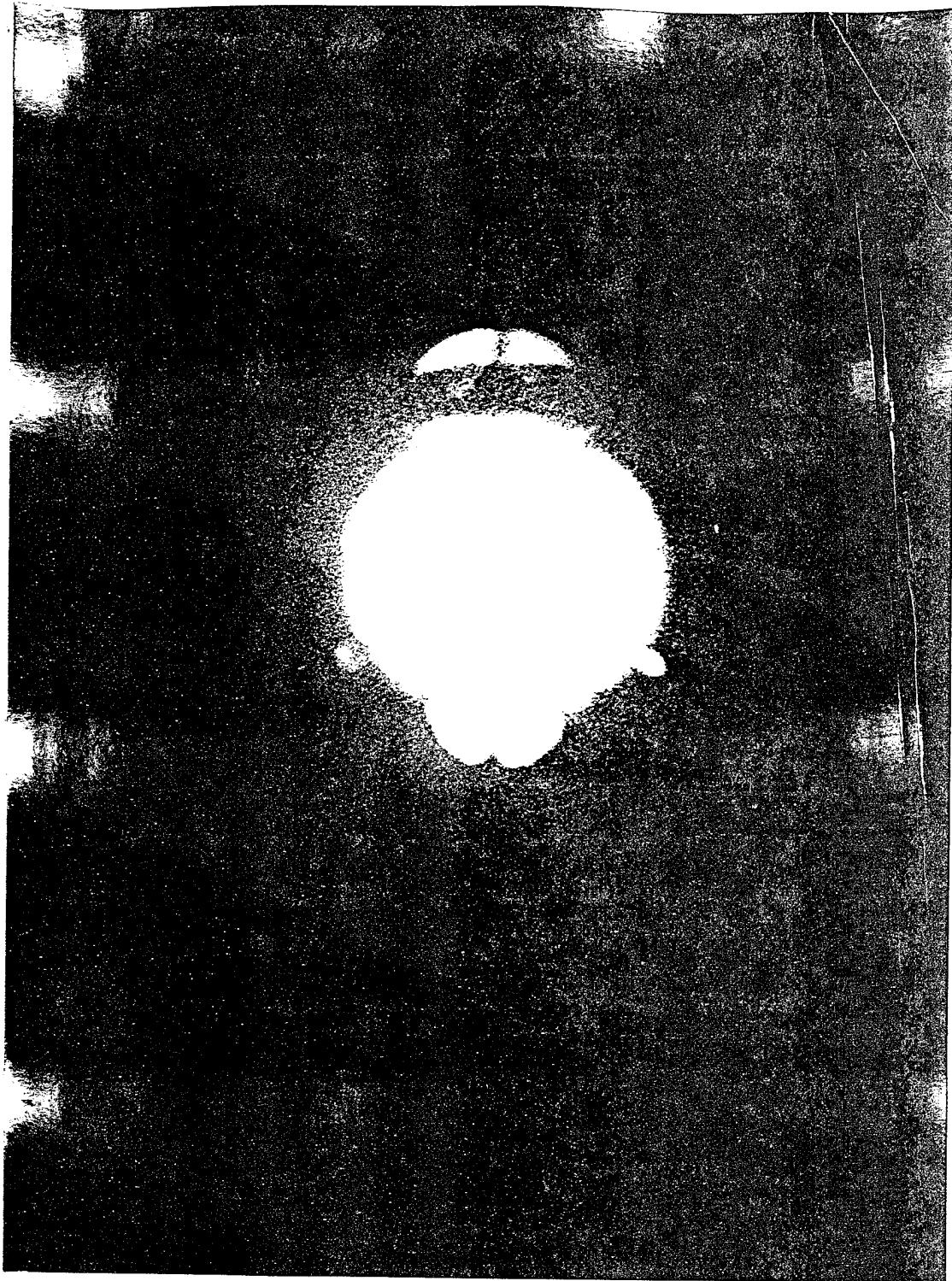
Time: 2.48 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

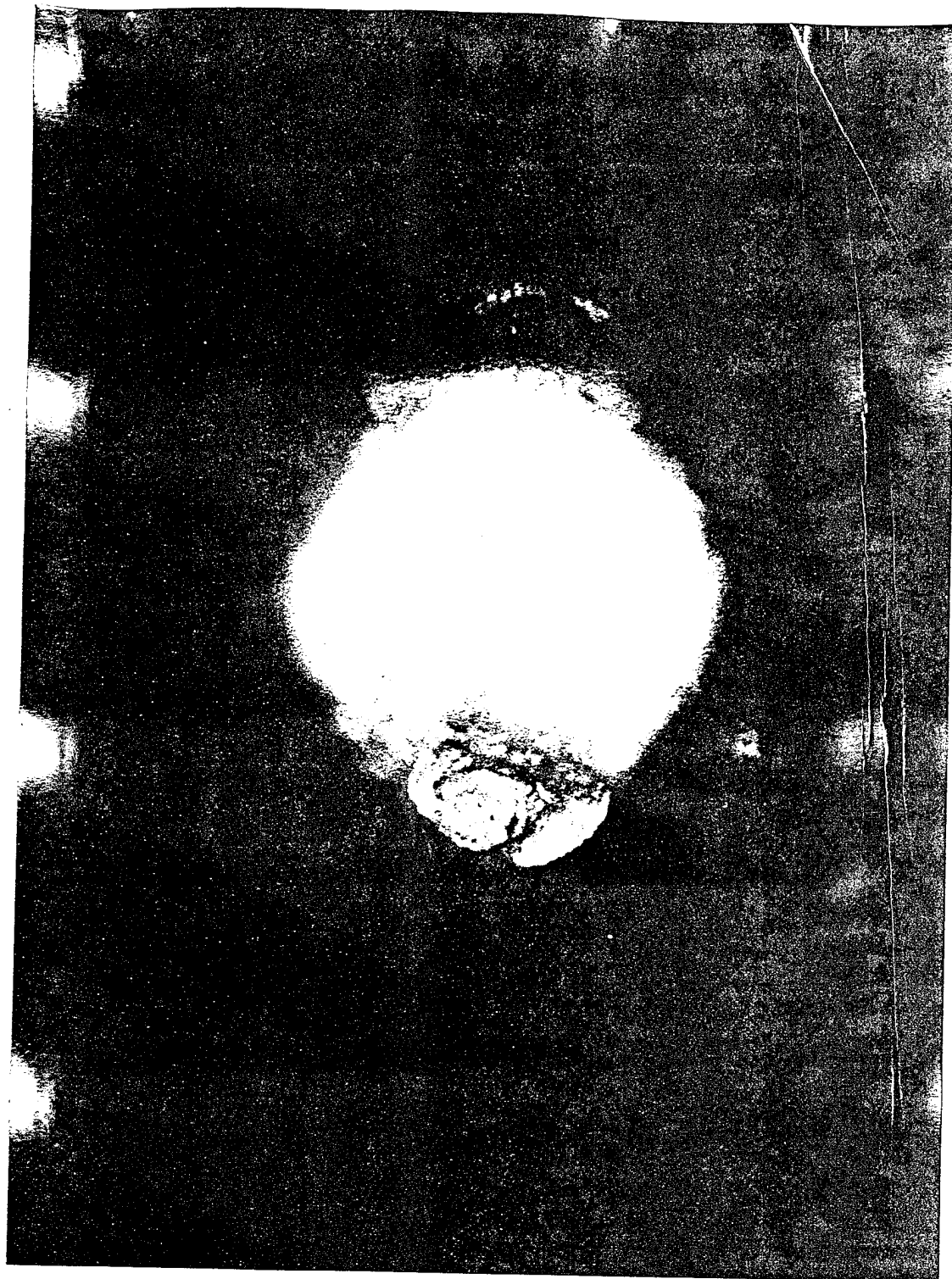
Time: 3.63 msec



Camera: R-34

Station: F-362 (6 x 6 No. 2)

Time: 3.17 msec



Camera: R-4

Station: F-369 (6 x 6 No. 3)

Time: 5.07 msec

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